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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b)

Attorney Docket No. 42390.P6147 Total Pages 7

First Named Inventor or Application Identifier Anne E. Miller ,et al.

Express Mail Label No. EL371006968US

ADDRESS TO: **Assistant Commissioner for Patents**
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APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents.

1. X Fee Transmittal Form
(Submit an original, and a duplicate for fee processing)

2. X Specification (Total Pages 19)
(preferred arrangement set forth below)
- Descriptive Title of the Invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to Microfiche Appendix
- Background of the Invention
- Brief Summary of the Invention
- Brief Description of the Drawings (if filed)
- Detailed Description
- Claims
- Abstract of the Disclosure

3. X Drawings(s) (35 USC 113) (Total Sheets 1)

4. X Oath or Declaration (Total Pages 5)

a. X Newly Executed (Original or Copy)

b. ___ Copy from a Prior Application (37 CFR 1.63(d))
(for Continuation/Divisional with Box 17 completed) **(Note Box 5 below)**

i. ___ DELETIONS OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).

5. ____ Incorporation By Reference (useable if Box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. ____ Microfiche Computer Program (Appendix)

7. _____ Nucleotide and/or Amino Acid Sequence Submission
(if applicable, all necessary)
a. ____ Computer Readable Copy
b. ____ Paper Copy (identical to computer copy)
c. ____ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. X___ Assignment Papers (cover sheet & documents(s))
9. __ a. 37 CFR 3.73(b) Statement (where there is an assignee)
X___ b. Power of Attorney
10. _____ English Translation Document (if applicable)
11. X___ a. Information Disclosure Statement (IDS)/PTO-1449
_____ b. Copies of IDS Citations
12. _____ Preliminary Amendment
13. X___ Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
14. _____ a. Small Entity Statement(s)
_____ b. Statement filed in prior application, Status still proper and desired
15. __ Certified Copy of Priority Document(s) (if foreign priority is claimed)

16. X___ Other: Copy of postcard with Express Mail Stamp (1 pg.)

17. **If a CONTINUING APPLICATION,** check appropriate box and supply the requisite information:
____ Continuation ____ Divisional ____ Continuation-in-part (CIP)
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18. **Correspondence Address**
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Approved for use through 09/30/00. OMB 0651-0032
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UNITED STATES PATENT APPLICATION

for

A CERIC-ION SLURRY FOR USE IN CHEMICAL-MECHANICAL POLISHING

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"Express Mail" mailing label number: EL371006968US
Date of Deposit: March 29, 1999
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A CERIC-ION SLURRY FOR USE IN CHEMICAL-MECHANICAL POLISHING

BACKGROUND OF THE INVENTION

1). Field of the Invention

The present invention relates to a slurry for use in chemical-mechanical polishing of a metal film on a semiconductor substrate.

2). Discussion of Related Art

The manufacture of integrated circuits involves the fabrication of multiple electronic devices such as transistors, diodes and capacitors in and on a silicon or other semiconductor wafer, and then interconnecting the devices with metal lines, plugs and vias.

During the manufacture of an integrated circuit, a number of layers of different materials are alternately deposited on one another and then partially removed. For example, during the formation of metal lines, a metal layer may be blanket deposited over the entire wafer so that metal of the metal layer covers higher areas on the wafer and fills trenches between the higher areas. The metal layer is then partially removed so that the higher areas are exposed and metal lines are left behind in the trenches.

One technique for removal of layers on a wafer is known in the art as "chemical-mechanical polishing". In a chemical-mechanical polishing operation,

a chemical-mechanical polishing slurry is applied over the metal layer which serves both a chemical and a mechanical function.

Chemically, a slurry of the above kind usually includes an oxidizer which oxidizes the metal layer by removal of electrons therefrom. An easily removable oxidized film is so formed by an upper portion of the metal film.

Mechanically, a slurry of the above kind also includes an abrasive such as silica (SiO_2) or ceria (CeO_2). The purpose of the abrasive is to abrade the oxidized film when a polishing pad is pressed against and moved over the film, and so remove the film.

Once the oxidized film is removed, the metal is again oxidized to form another oxidized film which is again removed utilizing the abrasive. The process is continued until the metal layer is removed to a required depth.

Slurries containing oxidizers may be unstable due to breakdown of the oxidizer over time resulting in unstable polish processes or production of toxic components. Replenishing and stabilizing these oxidizers are an added expense to be avoided. In addition, the spent slurry may have disposal issues and slurry oxidant requiring no waste treatment is desirable.

Another problem associated with the use of common chemical-mechanical polishing slurries is that they usually have pH values which are very low. Slurries having pH values which are very low are corrosive and may be the cause of damage to polishing equipment used in a chemical-mechanical polishing operation.

A further problem with conventional chemical-mechanical polishing slurries is that they cause "erosion", "dishing" and "recess" during polishing . Erosion is the preferential loss of a layer due to high metal pattern density, and dishing is the topography developed in a wide metal line due to the metal being

preferentially polished in the middle of the line with respect to the edge of the line. Recess, is the uniform loss of metal within a structure due to chemical activity and is typically dominant in narrow metal lines. Erosion, dishing and recess are undesirable as a planar surface is usually required.

SUMMARY OF THE INVENTION

The invention provides a chemical-mechanical polishing slurry comprising a liquid, cerium ions as an oxidizer, an abrasive, and a pH increasing substance. The cerium ions are in the liquid in a quantity equal to the inclusion of at least 0.02 molar ammonium cerium nitrate in the liquid. The abrasive is also included in the liquid. The liquid, the cerium ions and the abrasive jointly have a first pH value. The pH increasing substance increases the first pH value to a second pH value above 1.5.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is further described by way of example with reference to the accompanying drawings wherein:

Figure 1a is a side view illustrating a first layer, a barrier layer, and a metal layer which are formed on a substrate;

Figure 1b is a view similar to Figure 1a illustrating oxidation of a portion of the metal layer by a slurry;

Figure 1c is a view similar to Figure 1b illustrating removal of the oxidized portion with a polishing pad; and

Figure 1d is a view similar to Figure 1c illustrating how the barrier layer also acts as a polish stop layer.

DETAILED DESCRIPTION OF THE INVENTION

A chemical-mechanical polishing slurry, a method of preparing a chemical-mechanical polishing slurry, and a method of forming a metal line are described. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be evident, however, to one skilled in the art, that the present invention may be practiced without these specific details.

The invention provides a chemical-mechanical polishing slurry, comprising cerium ions as an oxidizer, and, in addition to the oxidizer, an abrasive. The slurry is environmentally green in the sense that it does not require waste treatment when depleted. Because the slurry contains very little cyanide, expensive recirculation or destruction processes for depleted cyanide containing slurries are avoided.

The slurry has also been found to be selective to barrier materials such as tantalum, tantalum nitride, titanium, or titanium nitride, which makes such a material a good choice for a polish stop.

Cerium ions may be provided by adding and mixing a complex double salt such as ammonium cerium nitrate [$(NH_4)_2Ce(NO_3)_6$] together with the abrasive in deionized liquid water. The ammonium cerium nitrate dissolves in the water to provide Ce^{+4} ions in solution in the water. The slurry preferably includes cerium ions in quantity equal to the use of 0.01 molar to 0.1 molar of

ammonium cerium nitrate. Other sources of cerium ions may alternatively be used, such as a simple salt like cerium tetrasulfate [$Ce(SO_4)_2 \cdot 2H_2SO_4$] or a double salt like ammonium cerium sulfate [$(NH_4)_4Ce(SO_4)_4 \cdot 2\,H_2O$].

The slurry may be applied over a copper or other metal layer which is formed on a semiconductor substrate such as a silicon wafer. Cerium ions of the slurry may oxidize (remove electrons from) copper of the copper layer according to one of the following formulas:

$$2Ce^{+4} + Cu \rightarrow Cu^{+2} + 2Ce^{+3}$$

$$Ce^{+4} + Cu \rightarrow Cu^{+1} + Ce^{+3}$$

The copper ions (Cu^{+2} or Cu^{+1}) may then react with the water within the slurry to form a copper oxide film such as Cu_2O or CuO which, with the assistance of the abrasive is easily removable from the remainder of the copper layer during polishing.

The abrasive in the slurry may be silica (SiO_2), ceria (CeO_2), alumina (Al_2O_3) or any other suitable abrasive. The slurry may include between 1 percent and 30 percent of the abrasive by weight, more preferably between 1 percent and 5 percent of the abrasive by weight.

In all the examples that follow, a slurry is applied to a copper layer on an 8 inch diameter wafer at a rate of 200 milliliter per minute, the wafer and a polishing pad are rotated relative to one another at 280 revolutions per minute, and a pressure of about 4 pounds per square inch is applied between the wafer and the polish pad.

Example 1

In one example a slurry was used which, in addition to deionize water, consisted of 0.05 molar ammonium cerium nitrate and 2.5 percent silicate by weight. The slurry has a pH value of 0.90. A polish rate of 5612 angstroms per minute (Å/min) was obtained. Polish uniformity across the wafer had a 1 σ variance of 8.3 percent.

In general, in the absence of a pH increasing substance, the slurry would have a pH below 1.5 if at least 0.02 molar ammonium cerium nitrate is used. To prevent damage to polishing equipment, the slurry preferably has a pH value of at least 1.5 and more preferably at least 2. The slurry may include a substance which increases its pH value. An amino acid such as glycine (NH_2- CH_2 -COOH) may be used to increase the pH value of the slurry. Glycine also acts as a copper complexor, i.e. it is a complexing agent which "grabs" onto oxidized copper thereby increasing copper ion solubility and so assists removal of the oxidized copper. The complexing is proposed to be similar to complexing by ammonia (NH_3) that occurs at a high pH such as described in the references of J.M. Steigerwald, et al, "Chemical Mechanical Planarization of Microelectronic Materials" by John Wiley & Sons, Inc., and of V. Brusic, et al, "Electrochemical Approach to Au and Cu CMP Process Development" by the Electrochemical Society Proceeding Vol 96-22 and 176-185. Other substances which may be used to increase a pH value of the slurry include potassium hydroxide (KOH) and ammonium hydroxide (NH_4 OH).

Example 2

In another example a slurry was used comprising 0.05 molar ammonium cerium nitrate, 2.5 percent silica by weight, and 1 percent glycine by weight. The slurry has a pH value of 1.65. A polish rate of 4770 Å/min was obtained. Polish uniformity had a 1 σ variance of 8.3 percent.

Example 3

In another example a slurry was used comprising 0.05 molar ammonium cerium nitrate, 2.5 percent silica by weight, and 2 percent glycine by weight. The slurry has a pH value of 2.26. A polish rate of 4784 Å/min was obtained. Polish uniformity had a 1 σ variance of 6.6 percent.

Example 4

In another example a slurry was used comprising 0.05 molar ammonium cerium nitrate, 2.5 percent silica by weight, and 3 percent glycine by weight. The slurry has a pH value of 2.43. A polish rate of 5653 Å/min was obtained. Polish uniformity had a 1 σ variance of 4.3 percent.

Example 5

In another example a slurry was used comprising 0.025 molar ammonium cerium nitrate, 1.25 percent silica by weight, and 2 percent glycine by weight.

The slurry has a pH value of 3.2. A polish rate of 2794 Å/min was obtained. Polish uniformity had a 1 σ variance of 5.0 percent.

It can be seen by comparing Example 5 with Examples 2 to 4 that, although a reduction in cerium ion concentration substantially increases the pH value of the slurry, polish rate also decreases substantially. It is therefore preferred that the slurry comprises cerium ions equal to at least 0.05 molar ammonium cerium nitrate, while still having a sufficient amount of glycine, or another pH increasing substance, so that the slurry has a pH value of at least 2.

When certain metal layers, such as nickel, chromium, tungsten or aluminum metal layers, are oxidized, a thin oxide film forms on the metal layer which passivates the remainder of the metal layer, i.e. the oxide film prevents further oxidation of deeper laying metal of the metal layer. The oxide film is easier to remove than the remainder of the metal layer so that only the oxide film is removed during polishing with the remainder of the metal layer resisting removal and thus forming a "polish stop". Copper, however, does not form a stable, non-porous passivating oxide layer, i.e. copper continues to oxidize until an oxidizing agent to which the copper is exposed is removed, and does therefore not form a polish stop.

It is believed that the fact that copper does not form a stable, passivating oxide, and a polish stop, is the cause of more local polish non-uniformity, or more dishing, when a copper layer is planarized in a chemical-mechanical polishing operation, than would be the case when a layer of another metal, which does form a passivating layer, is planarized.

An anti-oxidizing agent or corrosion inhibitor may be included in the slurry to control, or at least reduce, oxidation of a metal such as copper, with

corresponding less variation in polish uniformity or less dishing. One anti-oxidizing agent which may be used is benzotriazole (BTA, chemical formula: $C_6H_5N_2$)

Details of how BTA acts as an anti-oxidizing agent are described in the reference of R. Walker "Benzotriazole as a Corrosion Inhibitor for Antiques", Journal of Chemical Education, volume 57, 1980, pp. 789-791.

Example 6

Table 1 includes test results for a slurry containing 2.5 percent silicate by weight, 3 percent glycine by weight, 0.05 molar ammonium cerium nitrate, and BTA in varying quantities.

Table 1: Test results for varying amounts of BTA

BTA (molar)	pH	Polish Rate (Å/min)	1 σ variance in Polish Uniformity (percent)
0.00100	2.43	5653	8.3
0.00200	2.78	5884	3.3
0.00268	2.81	5790	2.7
0.00300	2.82	6158	3.4
0.00400	2.88	6594	4.0
0.00500	2.82	5801	10.5
0.00514	2.78	347	6.8
0.00600	2.88	86	150

It can be seen from Table 1 that 1 σ variance in polish uniformity is between 2.7 percent and 4.0 percent for BTA concentrations of between 0.00200

molar and 0.00400 molar. The 1 σ variance in polish uniformity increases significantly for BTA concentrations above 0.00400 molar. Polish rate also decreases significantly for BTA concentrations above 0.00400 molar. The slurry therefore preferably includes between 0.00200 molar and 0.00500 molar BTA in order to keep polish rate to at least 1000 Å/min, and more preferably includes between 0.00200 molar and 0.00500 molar BTA in order to obtain acceptable polish uniformity.

Although the aforegoing description is primarily directed towards a slurry and a method of preparing a slurry, it should be understood, from the aforegoing description, that the invention also extends to a method of forming metal lines. The method of forming metal lines is now further described with reference to Figures 1a to 1d.

Figure 1a shows a structure which is formed over a semiconductor substrate. A first layer 110, typically an interlayer dielectric layer, is formed over the substrate. An opening 112 is formed in the first layer 110.

A barrier layer 114 is deposited onto the first layer 110 and on side walls and within a base of the opening 112. The barrier layer 110 is typically of tantalum, tantalum nitride, titanium/titanium nitride and prevents outdiffusing of metal from a metal layer which is eventually formed in the opening 112.

A metal layer 116 is then deposited over the barrier layer 114. The metal layer 116 fills the opening 112 completely and covers the barrier layer 114. The metal layer 116 may be deposited in a conventional plating or vapor deposition process. The metal layer is typically made of copper but may be made of another metal such as tungsten.

As shown in Figure 1b, a slurry 118, of the aforedescribed kind, is then applied over the metal layer 116. The slurry comprises cerium ions in quantity sufficient to oxidize a portion 120 of the metal layer 116.

When, as shown in Figure 1C, a polishing surface of a polishing pad 122 is contacted against and moved over the metal layer, the oxidized portion of the metal layer 116 is removed. The slurry comprises abrasive in quality sufficient to assist in removal of the oxidized portion 120.

The process as shown in Figures 1a to 1c is repeated until, as shown in Figure 1d, the barrier layer 114 is exposed and a metal line 122 remains within the opening 112. The cerium ions in the slurry are selective in that only the material of the metal layer 116 is oxidized, and not the material of the barrier layer 114. The barrier layer 114 is thus used as a polish stop layer which prevents further removal of material.

Thus, a chemical-mechanical polishing slurry, a method of preparing a chemical-mechanical polishing slurry, and a method of forming a metal line are described. While certain exemplary examples and embodiments have been described, it is to be understood that such examples and embodiments are merely illustrative and not restrictive of the current invention, and that this invention is not restricted to the specific examples of embodiments described, since modifications may occur to those ordinarily skilled in the art.

CLAIMS

What is claimed:

1. A chemical-mechanical polishing slurry comprising:

a liquid;

cerium ions as an oxidizer in the liquid, the cerium ions being in a quantity equal to the inclusion of at least 0.02 molar ammonium cerium nitrate in the liquid;

an abrasive in the liquid, the liquid, the cerium ions and the abrasive together having a first pH value; and

a pH increasing substance in the liquid that increases the first pH value to a second pH value above 1.5.

2. The slurry of claim 1 comprising cerium ions in quantity equal to the inclusion of between 0.05 molar and 0.1 molar of ammonium cerium nitrate.

3. The slurry of claim 1 comprising between 1 percent and 30 percent abrasive by weight.

4. The slurry of claim 1 wherein the abrasive is silica.

5. The slurry of claim 1 wherein the second pH value is at least between 2.5 and 4.

6. The slurry of claim 1 wherein the substance is glycine.

7. The slurry of claim 1 which is environmentally green.

8. The slurry of claim 1 further comprising a complexing agent.

9. The slurry of claim 8 wherein the complexing agent is glycine.

10. The slurry of claim 1 further comprising an anti-oxidizing agent.

11. The slurry of claim 10 wherein the anti-oxidant is BTA.

12. The slurry of claim 11 comprising between 0.00200 molar and 0.00500 molar BTA.

13. The slurry of claim 1 comprising cerium ions in quantity equal to between 0.02 molar and 0.1 molar ammonium cerium nitrate and BTA comprising between 0.00200 and 0.00500 molar BTA.

14. The slurry of claim 13 wherein the second pH value is at least 2.5.

15. A method of preparing a chemical-mechanical polishing slurry, comprising:

adding together an abrasive and a complex cerium double salt as a source of cerium ions.

16. The method of claim 15, wherein the double salt is selected from the group consisting of ammonium cerium nitrate, and ammonium cerium sulfate.

17. The method of claim 15 wherein the double salt is ammonium cerium nitrate.

18. The method of claim 15 wherein the abrasive and the source of cerium ions, in solution, has a first pH value, the method further comprising adding a substance which increases the first pH value to a second pH value above 1.5.

19. The method of claim 18 wherein the substance is glycine.

20. The method of claim 18 further comprising adding a complexing agent.

21. A method of forming a metal line, comprising:

forming a first layer, with an opening therein, over a semiconductor substrate;

depositing a metal layer which fills the opening and covers the first layer;

applying a chemical-mechanical polishing slurry onto the metal layer, the slurry comprising cerium ions as an oxidizer, and an abrasive;

contacting a polishing surface against the metal layer; and

moving the polishing surface over the metal layer.

22. The method of claim 21 wherein the slurry comprises cerium ions in quantity sufficient to oxidize a portion of the metal layer, and the abrasive in

quantity sufficient to assist in removal of the oxidized portion when the polishing surface is moved over the metal layer.

23. The method of claim 21 wherein the metal layer is of a metal selected from the group consisting of copper and tungsten.

24. The method of claim 21 further comprising:

depositing a barrier layer over the first layer and before depositing the metal layer, the cerium ions selectively oxidizing the material of the metal layer over the material of the barrier layer.

25. The method of claim 21 wherein the metal layer is removed at a rate of at least 1000 angstroms per minute.

ABSTRACT OF THE DISCLOSURE

The invention provides a chemical-mechanical polishing slurry comprising a liquid, cerium ions as an oxidizer, an abrasive, and a pH increasing substance. The cerium ions are in the liquid in a quantity equal to the inclusion of at least 0.02 molar ammonium cerium nitrate in the liquid. The abrasive is also included in the liquid. The liquid, the cerium ions and the abrasive jointly have a first pH value. The pH increasing substance increases the first pH value to a second pH value above 1.5.

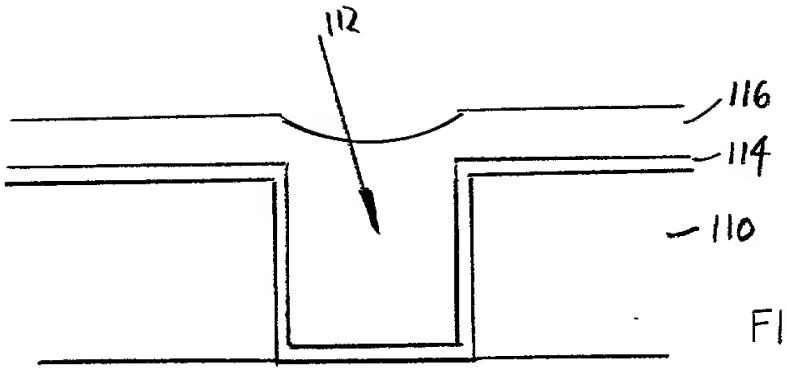

FIG 1a

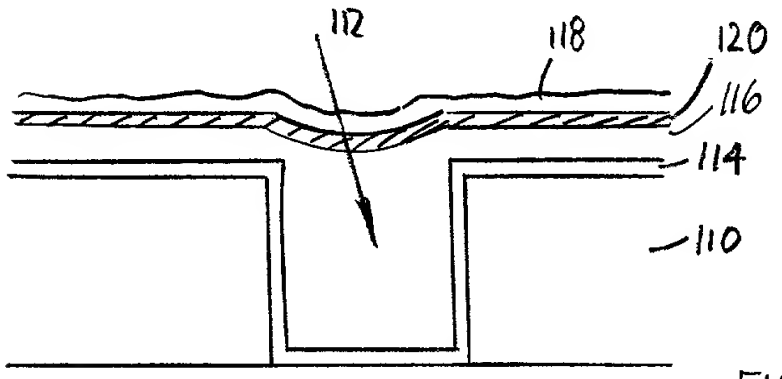

FIG 1b

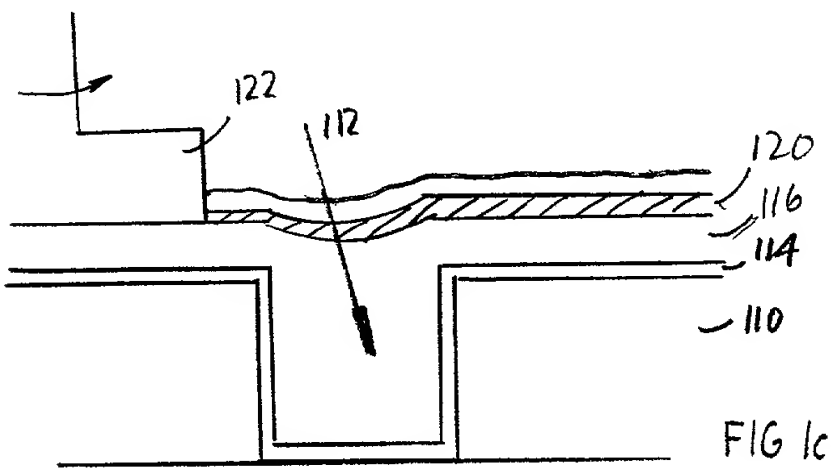

FIG 1c

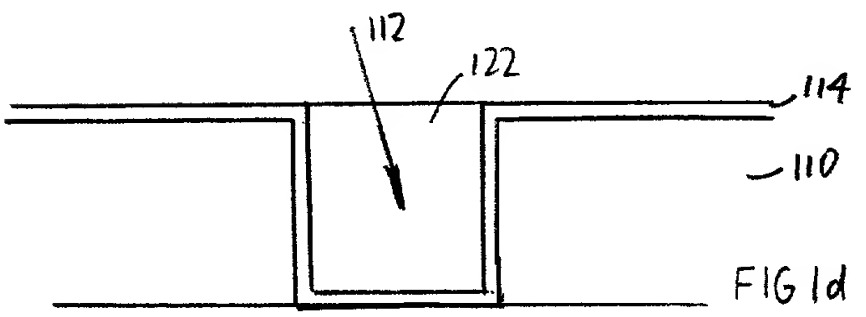

FIG 1d

Attorney's Docket No.: 42390.P6147 PATENT

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION
(FOR **INTEL CORPORATION** PATENT APPLICATIONS)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

A CERIC-ION SLURRY FOR USE IN CHEMICAL-MECHANICAL POLISHING

the specification of which

XX is attached hereto.
_____ was filed on _____ as United States Application Number _____ or PCT International Application Number_____ and was amended on _____.
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, and that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

Priority Claimed

(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No

I hereby claim the benefit under title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below

(Application Number)	Filing Date
(Application Number)	Filing Date

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Number)	Filing Date	(Status -- patented, pending, abandoned)
(Application Number)	Filing Date	(Status -- patented, pending, abandoned)

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Title 37, Code of Federal Regulations, Section 1.56
Duty to Disclose Information Material to Patentability

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclosure information exists with respect to each pending claim until the claim is cancelled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is cancelled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclosure all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) Prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) The closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made or record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application;

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.